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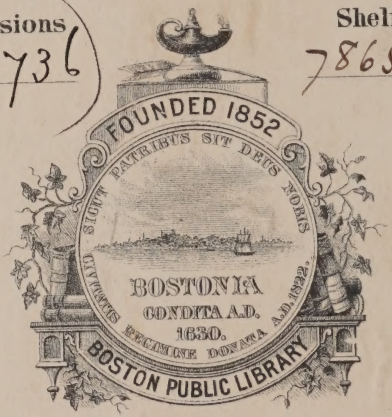

Received July 20, 1892

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PROF. J. P. COOKE

ON CRYOPHYLLITE.

[From the American Journ. of Science and Arts, Vol. XLIII, March, 1867.]

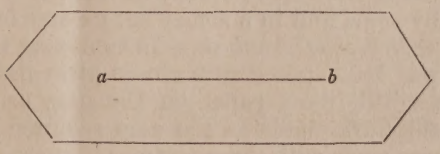
ON CRYOPHYLLITE,

a new mineral species of the Mica Family, with some associated minerals in the granite of Rockport, Massachusetts.

BY JOSIAH P. COOKE, Jr.

In a paper published in a recent number of this Journal* I described a new mineral species allied to Helvin, to which I gave the name of Danalite. Associated with Danalite in the granite ledges forming the extremity of Cape Ann, Massachusetts, are two remarkable micas, one of which is the new species to which on account of its easy fusibility and foliated structure I have given the name Cryophyllite.

Mineralogical Characters.—The mineralogical characters of cryophyllite are as follows. Like other varieties of mica it crystallizes in six-sided prisms, which are frequently of considerable size, from one to two inches in length and of proportionate diameter. The basal cleavage is highly perfect, yielding thin flexible and transparent laminæ, which when examined with a polarizing microscope give a biaxial image, the angle between the optical axes varying from 55° to 60°. The angles 55°, 57° 30′, and 60°, were all measured on different specimens. The dispersion of the axes, if any, is so slight that its character could not with certainty be determined, the color of the mineral tending to obscure any such effect. The perfect uniformity of the two systems of rings both as to form and to color indicates that the mica belongs to the trimetric system. Nevertheless, the angle between the prismatic planes measured with an application goniometer 120° as accurately as is possible with this instrument, and in one instance the planes of an hexagonal pyramid terminating the prism were distinctly seen. Considering, however, these crystals as belonging to the trimetric system, in accordance with the generally received opinion of mineralogists as to crystals of the mica family, all of which present essentially the same crystallographic characters, we must regard the six-sided prism of cryophyllite as formed by the union of the planes I of the rhombic prism with the brachydiagonal basal planes $\breve{i}\breve{i}$. The plane of the optical axes coincides with the shorter diagonal of the rhomb base, and the crystals are frequently much elongated in this direction, so that the form of the cleavage face was as shown in the accompanying figure, the line $a\,b$ indicating the position of the plane of the optical axes. Furthermore, the crystals were frequently twinned together



* Vol. xlii, No. 124, July, 1866.

on the plane $i\breve{i}$, and it was observed that in such cases the planes of cleavage of the two crystals were absolutely coincident, proving that the rhombic prisms are rectangular and not oblique, as De Senarmont has previously shown to be true of other crystals of the mica family.

The color of cryophyllite in axial directions is dull emerald green, not unlike glass colored with protoxyd of iron, and so deep that the laminæ are opaque unless quite thin, but like other colored micas it is dichrous and appears brownish-red in the direction of the lateral axes. The color of the streak is light gray with a tint of green. The luster is brilliant on the cleavage face inclining to resinous. The hardness is from 2 to 2·5 and the specific gravity 2·909.

Before the blowpipe cryophyllite very easily fuses with some intumescence to a greyish enamel bead, and it even fuses in flakes of considerable size in the flame of a candle, so that its fusibility is from 1·5 to 2 of von Kobell's scale. It imparts to the flame of a Bunsen's lamp a most brilliant lithia reaction, and by examining the colored flame with a spectroscope the presence of potassium, sodium and rubidium may also be readily discovered. The amount of sodium however must be exceedingly small as it does not sensibly modify the lithia flame as seen by the naked eye, and the same is true to a still greater degree of rubidium. The presence of rubidium is best recognized by mixing the pulverized mineral with pure pulverized sulphate of lime, exposing a small bead of this mixture supported by a loop of fine platinum wire to the flame of a gas blowpipe and examining the flame with a spectroscope. The characteristic double blue line of rubidium is then seen very distinctly for a few moments, but soon disappears. No trace of cæsium could be discovered, either by the mode of experimenting just described or by examining the platinum salt obtained in the course of the analysis, by the partial precipitation of the alkalies with chlorid of platinum.

Heated alone in a closed glass tube cryophyllite slightly changes color, but gives no sublimate, although when heated in the same with bisulphate of potash it gives a strong reaction of fluorine. When in fine powder, it is completely decomposed after some time even by the dilute mineral acids, the silica separating as a fine powder. From this description it is evident that in its mineralogical characters cryophyllite closely resembles other members of the mica family, especially the lepidolites, differing from these chiefly in the ease with which it is decomposed by acids and in a somewhat greater fusibility.

Method of Analysis.—In analyzing the mineral the fine powder was decomposed in a closed glass flask in the same way as described in my paper on Danalite, using dilute hydrochloric or sulphuric acids as the case required. Each complete analysis was made with three portions of the same powder. From the first

portion, decomposed by hydrochloric acid, the silica, manganese, iron and aluminum were determined, the last two being precipitated as basic acetates and weighed together as oxyds, and the manganese subsequently precipitated from the filtrate by bromine. From the second portion, decomposed by dilute sulphuric acid, with perfect exclusion of air, the amounts of protoxyd and sesquioxyd of iron were determined by means of permanganate of potash, when by subtracting the total quantity of iron, calculated as sesquioxyd, from the sum of the alumina and sesquioxyd of iron already known, the amount of alumina was ascertained. From the third portion of the powder, decomposed by hydrochloric acid, the magnesia and the alkalies were determined. The alkalies were weighed as sulphates, and from the amount of sulphuric acid subsequently determined, the relative quantities of potash and lithia were calculated. From the fourth portion of the powder the quantity of fluorid of silicon was determined. In the first analyses of the mineral the fluorine was precipitated as fluorid of calcium according to the well known method of Berzelius as modified by Rose; but the process was found to be very tedious and the results not accordant. Subsequently the following method was devised, which may be found to be useful in other cases.

Determination of Fluorid of Silicon.—A weighed amount of finely pulverized mineral is first decomposed in a tared platinum dish with dilute sulphuric acid, and the greater part of the water having been removed on a steam bath and the excess of sulphuric acid having been driven off by gradual heating on a sand bath, the whole mass is ignited during at least an hour, the dish meanwhile being covered with a piece of platinum foil forming part of the tare. The dish with its contents having been weighed, the dried mass is next treated with hydrochloric acid and the residual silica determined in the usual way, and in the filtrate from the silica the sulphuric acid is determined and weighed as sulphate of baryta. We thus obtain four weights: A, the weight of the mineral employed in the analysis; B, the weight of the ignited residue; C, the weight of the residual silica; and D, the weight of the residual sulphuric acid. It is now evident that A+D−B equals the weight of the fluorid of silicon, and that B−C−D equals the weight of the sum of all the bases present. The iron is of course present in the residue as sesquioxyd, but in order to ensure its complete oxydation, it is important to add a few drops of nitric acid to the decomposed mineral, before expelling the excess of sulphuric acid. The sum of the weights of all the bases, which we find incidentally as one of the results of this method, not only furnishes an important control of the rest of our analysis, but also enables us to test the accuracy of our method. In the analysis given below it appears that the

sum of the bases each separately determined as the mean of two analyses equals 45·03 per cent, while the sum of the bases weighed together in the method just described equals 45·18 per cent, as the mean of three determinations. A closer agreement than this could not possibly be expected. The process is comparatively short and presents no unusual difficulties. The chief liability to error is in the determination of the sulphuric acid, and it is necessary in washing the sulphate of baryta to take great care to remove the impurities, which this precipitate is apt to carry down; but the methods recommended by Rose and Fresenius were found to be generally sufficient for the purpose. Nevertheless, when the amount of fluorine is less than one per cent, the old process is to be preferred.

Results of Analysis.—Two very distinct varieties of cryophyllite were analyzed,—the one finely foliated and consisting of an aggregate of small crystals and the other in large distinct crystals imbedded in massive feldspar; but no other differences of character were observed, and they were found to have the same percentage composition. The purest material was selected for analysis and such as had evidently never undergone the slightest change. There is probably in all the analyses a small loss of silica, but the error, if any, is in that direction. The results are given in the following table. In columns 1 and 2, we have the complete analyses made as first described of the large crystals, while in columns 3, 4 and 5, we have the partial analysis made of the more finely foliated variety by the process last described in connection with the determination of fluorid of silicon.

Analysis of Cryophyllite from Rockport.

	1.	2.	3.	4.	5.	Mean.	Oxygen.	
Silica,	51·53	51·54	51·65	51·37	51·36	51·49	27·46	
Fluorid of silicon,			3·29	3·34	3·62	3·42	1·06	=28·52
Alumina,	16·76	16·77				16·77	7·82	
Sesquioxyd of manganese,	0·33	0·35				0·34	0·10	
Sesquioxyd of iron,	2·00	1·94				1·97	0·59	= 8·51
Protoxyd of iron,	8·00	7·96				7·98	1·76	
Magnesia,	0·76		45·06	45·29	45·02	0·76	0·30	
Potassa,	13·14	13·16				13·15	2·23	
Lithia,	4·05	4·06				4·06	2·16	= 6·45
Soda,	*trace.*					*trace.*		
Rubidia,	"					"		14·96
						99·94		

Oxygen ratio, 14·96 : 28·52

14·26 : 28·52 = 1 : 2.

General formula, RO, SiO_2. Probable rational formula, $(\frac{1}{2}\dot{R}^3 . \frac{1}{2}\ddot{R}), 3\dot{S}i$.

The fluorine in the mineral is so firmly incorporated that, as stated above, it is not driven out even by a red heat, and there can be no doubt that it replaces a portion of the oxygen of the silica in the proportion of one equivalent of fluorine to every twenty-eight of oxygen. The ratio of the oxygen of the prot-

oxyds to that of the sesquioxyds is as 13 to 17, but if we estimate all the iron as protoxyd, assuming with many mineralogists that a sesquioxyd base may under certain conditions replace a protoxyd base, we shall then have very nearly a ratio of equality and may then write our general symbol $(\frac{1}{2}\dot{R}^3 . \frac{1}{2}\ddot{R})$, $3\ddot{S}i$.

As has already been stated, the physical characters of the new mineral do not differ essentially from those of other well known micas, and even its greater fusibility is shared with some varieties of lepidolite, resulting probably from the very large amount of alkali which the silicate contains. The ground on which this mica must be regarded as a new species is the definite oxygen ratio of 1 to 2, which has never before been observed among the micas. The five analyses given above of two distinct varieties, from different localities, differing markedly in appearance, leave no doubt in regard to the definiteness of this ratio, and no more specific character for a new species than this could be desired. When now we consider the very great want of definiteness in the micas as a class, their composition varying between $2RO, SiO_2$ in several varieties, and RO, SiO_2 in cryophyllite, it would appear that the new mica has a distinct typical character, forming as it were one boundary of this family of minerals. Moreover, it is at least a probable theory that the two formulæ just given represent the only two distinct types of micas, and that the variation of composition may result from an admixture of these two isomorphous species. The masterly investigations of De Senarmont on the optical relations of the micas tend to show that such an admixture exists, and at least prove that even a very large difference in the angle of the optical axes does not afford a safe ground for making a distinction in species. He supposed that this difference arises from a mixture of two micas crystallographically isomorphous but optically distinct, the one, and the more common class, having the optical axes in the plane of the longer diagonal, while in the other they fall in the plane of the shorter diagonal, as is the case with cryophyllite. Moreover, he was enabled, by crystallizing together certain isomorphous salts, to produce artificially the same result, which we have naturally in the micas. If then the variation of optical characters results from an isomorphous mixture of *optically* distinct species, it is at least probable that the variation of composition, so far as the oxygen ratio is concerned, may be caused by a similar mixture of *chemically* distinct species, and this view may serve to bring into some sort of order the almost hopeless confusion which the analyses of micas have hitherto presented. The magnesian micas phlogopite and biotite are sufficiently distinguished by the character of their bases, and conform very closely to the general formula $2RO, SiO_2$; but there does not seem to be any good ground for distinguishing between

the two. The optical distinction, as we have seen, is not specific, and if sesquioxyds may replace protoxyds, any apparent difference in the relative proportions of these oxyds is equally of no value as a ground of separation. Even this last difference, however, is not constant, and biotite must be regarded as a phlogopite in which a certain amount of magnesia has been replaced by protoxyd or sesquioxyd of iron. Passing next to lepidomelane, we have a pure iron mica in which all the magnesia has been in like manner replaced. Lastly, the presence or absence of a small and very variable amount of lithia does not seem to make any good ground of distinction between lepidolite and muscovite, and the only essential difference between these species is the much greater fusibility of the former, arising probably from the large amount of alkali and fluorine entering into its composition, a quality which we have endeavored to express by the name cryophyllite, following the analogy of the name cryolite. In lepidolite the oxygen ratio varies very widely between the extreme limits already named, the variation resulting, according to our theory, from a mixture of two species, the first having the type ratio 1 : 1, which we may still call lepidolite, and the second having the ratio 1 : 2, which has been described in this paper and called cryophyllite. A similar admixture of an isomorphous species having the type ratio 1 : 2 may explain the equally wide variations in the oxygen ratio of the muscovite, although the infusible mica corresponding to cryophyllite has not yet been observed. It is manifest that the theory here advanced would be very greatly substantiated if it could be shown that cryophyllite is actually associated with a distinct but isomorphous mica having the type ratio 1 : 1, and that it does actually influence the composition of its associate in the way we have indicated. Such is the case, as we believe, at the Rockport locality.

Lepidomelane.—The mica which is associated with cryophyllite at Rockport (or as we should rather say, with which cryophyllite is associated, for cryophyllite is the subordinate species) is an iron mica of the species lepidomelane. This is the common mica of the great granite ledges which form the extremity of Cape Ann. In the granite itself, however, it occurs only in small flakes forming a very small proportion of the whole mass; but in the numerous veins which intersect the rock, lepidomelane is found in crystals of considerable size and sometimes in plates several inches in diameter. The vein, from which most of the best specimens have been taken, is an offshoot of one of the great trap dikes which cross the Cape from north to south nearly parallel to each other, and consists chiefly of massive quartz and feldspar almost completely segregated, the quartz lining the lower wall, while the feldspar lines the hanging wall

of the vein. The best crystals, both of lepidomelane and of cryophyllite, are found in the massive feldspar, sometimes in direct contact and interpenetrating each other, while at other times they are comparatively isolated. The crystals of the two minerals resemble each other so closely in their external aspect that it requires some experience to distinguish them, without applying the distinctive test soon to be mentioned, and even an experienced mineralogist might readily mistake an aggregate of the two for a homogeneous mass. Like cryophyllite the lepidomelane crystallizes in hexagonal prisms with an angle of 120° between the prismatic planes, as was measured on several specimens with an application goniometer. Moreover the crystals have the same general habitus as those of the associated mica. They are frequently seen elongated in the direction of the brachydiagonal and twinned together on the plane $i\breve{i}$, and, in a word, the description of the crystals of cryophyllite already given applies equally well to those of lepidomelane; but unfortunately on account of the great opacity of lepidomelane I have not yet succeeded in determining its optical relations. There can be no doubt, therefore, that the two micas are perfectly isomorphous. But while the outward resemblance of these micas is so striking, the mineralogical characters of the two species are wholly distinct, as will be seen from the following description.

Mineralogical characters of Rockport Lepidomelane.—The cleavage is basal and perfect, but it is not so eminent as in most micas, and the foliæ are not at all or only slightly elastic. The color is black, and that of the streak dark green, differing wholly from the color of the streak of cryophyllite, which is light gray with only a faint tinge of green. The laminæ are opaque unless exceedingly thin. The luster is very brilliant, inclining to resinous on the cleavage face. The sp. gr. was found to be 3·169, and the hardness about that of calcite, or 3. Before the blowpipe it fuses to a black enamel bead, which is highly magnetic, and this affords another ready means of distinguishing it from cryophyllite. The fusibility is about that of iron-garnet, or between 3 and 4 of von Kobell's scale. With borax it forms a bottle-green glass. The powder when heated in a closed glass tube gives off water, and its green color changes to a pinchbeck-brown not unlike that of magnetic pyrites. Heated with bisulphate of potash it gives a slight reaction for fluorine. The powder is easily decomposed by the dilute mineral acids, the silica separating in fine scales. These characters agree very closely with those of the original lepidomelane from Wermland as described by Soltmann,* only the more perfect crystals from Rockport enable us to determine the crystalline form with more cer-

* Pogg. Annalen, l, 664, also Dana's System, 4th edition, vol. ii, page 297.

tainty than was possible with the minute scales from which the species was first established.

Analysis of Rockport Lepidomelane.—My analyses of this mica are given in the following table. In the analyses 2, 3, and 4, the same methods were followed which have already been described in connection with cryophyllite. In analysis 5, I employed, with some slight modification, the method first proposed by H. Saint Claire Deville,* and the close agreement of the figures obtained by such very different methods serves to confirm the general accuracy of the result. The determination of the water was the chief difficulty met with in the analyses. The water enters so intimately into the composition of the mineral that it is not expelled below a low red heat, and then only quite slowly. Moreover at this temperature the mineral is rapidly oxydized. But by igniting the mineral in a current of carbonic acid gas the oxydation was prevented and constant results were obtained. With this precaution portions of the same powder were ignited, first without and then with oxyd of lead with the following results:

	1.	2.	3.	Mean.
Loss on ignition without PbO,	1·54	1·52	1·52	1·53
" " with "	1·55	1·40		1·48

The difference is within the limit of probable error, and the results prove that the fluorine is not expelled at a low red heat. Moreover the mineral after ignition gave as strong a reaction for fluorine as before, and when heated to the highest temperature which could be obtained with a gas blast lamp, underwent no farther loss of weight. This is in accordance with what we found to be true of cryophyllite; but not in accordance with the comportment of hydrous minerals into which fluorine enters as an essential constituent. Compare analyses of Cookeite, this Journal, [2], xli, 246. These facts, taken in connection with the circumstance that fluorine was not found by Soltmann in the lepidomelane of Wermland, lead to the inference that the fluorine in the Rockport mineral is an accidental constituent, derived from the admixture of material foreign to the species itself. The amount of fluorid of silicon in analysis 2 was determined by the method of Berzelius; but the limit of error in this process is so wide that the result can only be regarded as approximate. The analyses which follow were all made on material dried at 100°, and selected to represent the different varieties of the mineral found at Rockport. Analyses 2 and 3 were made from portions of a mass of comparatively compact material. No. 4 from a perfect crystal imbedded in the massive feldspar of the vein already referred to, and the silica determination. No. 1 from scales picked out from the granite of Boylston Hall in Cambridge, which is built of stone from the Rockport quarries.

* Annales de Chimie et de Physique, [3], xxxviii, 5.

Analysis of Rockport Lepidomelane.

	1.	2.	3.	4.	5.	6.	7.	8.	Mean.	Oxygen.	
Silica,	39·50	39·49	—	39·79	39·43	—	—	—	39·55	21·09	
Fluorid of silicon,		0·62	—	—	—	—	—	—	0·62	0·19	=21·28
Alumina,		16·72	16.41	16·90	16·87	—	—	—	16·73	7·81	
Sesquiox. of manganese,		—	0·63	0·58	0·59	—	—	—	0·60	0·18	
Sesquiox. of iron,		—	—	—	—	12·21	12·01	11·98	12·07	3·62	
Protox. of iron,		—	—	—	—	17·57	17·47	17·41	17·48	3·88	
Magnesia,		—	—	0·64	0·59	—	—	—	0·62	0·25	
Potassa,		—	—	10·68	10·63	—	—	—	10·66	1·81	
Lithia,		—	—	0·60	0·57	—	—	—	0·59	0·32	
Soda,		—	—	—	—	—	—	—	*trace.*	—	
Rubidia,		—	—	—	—	—	—	—	"	—	
Water,		—	—	1·55	1·40	1·52	1·52	1·54	1·50	1·33	=19·20
									100·42		

Oxygen ratio, 19·20 : 21·31.

After an examination of the results of the above analyses no one can doubt that the true oxygen ratio of the mineral is 1 : 1, and that the general formula is $2RO, SiO_2$ or $2(\frac{1}{3}\dot{R}^3 . \frac{1}{3}\ddot{R})3\dot{S}i$. This is not only the nearest probable formula, but moreover it harmonizes with the well established formulæ of allied species and with the results of Soltmann's analysis of lepidomelane, a mineral which our Rockport mica resembles most closely in all its characters. Nevertheless the discrepancy between the actual and the probable ratio is very great, and cannot possibly be referred to impure material or imperfect processes. As has been already stated, the material used in the fourth analysis was a portion of a perfect crystal completely isolated in a mass of feldspar, and the results of this analysis agree almost precisely with those obtained in No. 5 by an entirely different process and with wholly different material. Here then are the same unsatisfactory results, which have been obtained again and again in the analyses of the micas, and have made it so difficult to reduce to order this important family of minerals. Fortunately we find at the Rockport locality what I believe to be the clue to the whole mystery. The common mica of the granite is there associated with a second mica containing twice as much silica, but still perfectly isomorphous with it in crystalline form. Now if two isomorphous salts crystallize together from the same solution, we obtain crystals which are mixtures of the two in definite proportions, the proportions depending chiefly on the relative quantity of each which may be present; but also at times on other conditions less accurately determined.* When the sedimentary rocks were undergoing the metamorphism which converted them into the granite ledges of Rockport, or when by any other means this granite was formed, the two isomorphous micas, described in this paper, did actually crystallize together, for so we find them; and it is reasonable to suppose that the same results followed in the one case as in the other, and that

* See Rammelsberg's important paper on this subject, Pogg. Ann., xci, 321.

the mica of the Rockport granite is an isomorphous mixture of these two distinct species. This conclusion, moreover, is favored by the fact that lepidomelane—the species to which this mica undoubtedly belongs—contains in other localities neither lithia nor fluorine; while on the other hand these same ingredients are strikingly characteristic of the lepidolite micas, to which cryophyllite is allied. Assuming then that the lithia and fluorine in the analyses belong to the cryophyllite and not to the lepidomelane, we have endeavored in the following table to eliminate this disturbing element from our results. Thus, in column 1 we have repeated the mean result of our analyses. In column 2 we have the amounts of the several ingredients of cryophyllite corresponding to 0·59 per cent of lithia, deduced from the analyses of this mineral given above. Subtracting these quantities from those in the first column we have the numbers in the third column. In column 4 we have reduced the same to a percentage composition, and these numbers, according to our theory, represent the true composition of the Rockport lepidomelane. In column 5 we have placed for comparison the analysis of lepidomelane by Soltmann.

Reduction of analyses of Lepidomelane.

	1.	2.	3.	4.	Oxygen.	5.	Oxygen.
Silica,	39·55	7·48	32·07	**37·39**	....=19·94	**37·40**	=19·94
Fluorid of silica,	0·62	0·50	....	....	....		
Alumina,	16·73	2·44	14·29	**16·66**	7·78	**11·60**	5·42
Sesquiox. of manganese,	0·60	0·05	0·55	**0·64**	0·19		
Sesquiox. of iron,	12·07	0·29	11·78	**13·74**	4·12	**27·66**	8·29
Protoxyd of iron,	17·48	1·16	16·32	**19·03**	4·23	**12·43**	2·76
Magnesia,	0·62	0·11	0·51	**0·59**	0·24	**0·26**	0·10
Potassa,	10·66	1·91	8·75	**10·20**	1·73	**9·20**	1·61
Lithia,	0·59	0·59	....	....	....		
Water,	1·50	....	1·50	**1·75**	1·56=19·85	**0·60**	0·53=18·71
				100·00		**99·15**	

Oxygen ratio, 19·85 : 19·94 = 1 : 1.

General formula $2RO, SiO_2$. Probable rational formula, $2(\frac{1}{4}\dot{R}^3, \frac{1}{4}\ddot{R})3\ddot{S}i$.

The result of our calculation, as will be seen, is most satisfactory; for not only is the oxygen ratio thus obtained exact, but also the numbers agree very closely with those of Soltmann, the only apparent discrepancies disappearing when the sum of the alumina and the oxyds of iron and manganese are compared together in the two analyses, and the difference in the distribution of the iron between the two oxyds is unimportant if we assume as before that the oxyds may replace each other. We have estimated in both analyses the amount of water among the bases for the following reasons, which seemed to us conclusive: first, because the loss of water is attended by a very marked change in the color of the mineral—from green to brown—

proving that the water must be chemically, and not merely hygroscopically, combined; secondly, because while water of crystallization would be present in a definite number of equivalents —one or more—the quantity of water in this mineral obeys no such law, and only amounts to a small fraction of a single equivalent; lastly, because the water is only driven out at a high temperature, indicating that it is in a state of intimate combination. There does not appear to be any simple relation between the amounts of the protoxyd and sesquioxyd of bases in the Rockport lepidomelane; but the general formula of the mineral may readily be reduced to that of the magnesian micas by assuming that a portion of the protoxyd of iron has been replaced by the sesquioxyd.

The facts advanced in this paper seem to show quite conclusively that the variation in composition of the Rockport lepidomelane from the normal type is caused by the admixture of a second isomorphous mica with a higher oxygen ratio, which we have called cryophyllite, and this being the case we may expect to find that similar variations in the composition of other micas are due to a similar cause, and it will therefore be interesting to search for the disturbing element at the various localities. Such an examination will be likely to reveal either the presence of cryophyllite itself or else of some new species analogous to it; and if the Rockport locality is any guide, such minerals are more likely to be found in feldspathic veins or nodules of the granite rather than uniformly diffused through the rock itself. It is a fact worthy of notice, and which is quite evident from the above analyses, that the proportions in which cryophyllite is mixed with lepidomelane are quite constant throughout the Rockport locality; and this again is wholly in accordance with the well known facts which have been developed by Rammelsberg* and others in regard to the crystallization of isomorphous salts when mixed together in the same solution. It appears from these investigations that isomorphous salts do not necessarily crystallize together in every proportion, but that, in most cases at least, any two given salts have, so to speak, a definite capacity for each other, and that when the point of saturation is passed, pure crystals of the salt in excess may be deposited in direct contact with those which are mixtures of the two. Such experiments furnish an exact counterpart of the conditions which we actually realize in the Rockport granite.

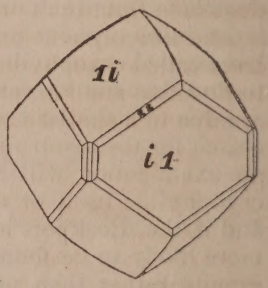
Albite.—The general nature of the vein in which the best crystals, both of cryophyllite and lepidomelane, have been found, has already been described in the earlier part of this paper. This vein consists chiefly of quartz and feldspar of the ortho-

* Pogg. Ann., vol. xci, p. 321.

clase variety. Very fine green colored crystals of the last have been obtained here, and good crystals of the usual color are abundant. Associated with the orthoclase I have frequently noticed a compact variety of albite distinguished by a peculiar luster and very marked striation on the plane of easy cleavage. It resembles somewhat, in outward aspect, oligoclase, but the mineral had the characteristic cleavages of a clinoclase feldspar, and the angle *O* on *ii* measured with an application goniometer 93°. Moreover it contains, if any, only the merest trace of lime. The albite is actually imbedded in the orthoclase, and the intimate association of these two heteromorphous species is worthy of notice.

Malacone.—The same vein contains also a peculiar variety of zircon, which is probably identical with the malacone of Scheerer, only somewhat more altered. The crystals have the general form represented in the figure, and resemble the crystals of zircon from Expailly in France. On account of the great predominance of the planes 1*i* and *i*1, they resemble the rhombic dodecahedron of the regular system, and can only be distinguished from this form by the distribution of the modifying planes; since on account of the strong curvature of the faces the limits of necessary uncertainty in the measurement of the angles cover the whole difference between this form and the corresponding form of zircon. In the ordinary method of representing the crystals of zircon the relation of the forms just referred to does not appear; but if we refer the planes of the zircon crystals to axes corresponding in position to those of the allied form of the regular system, the really close affinity of the two becomes evident. Thus the ratio of the axes, which in the regular system is unity, is in zircon $a:b=0{\cdot}906:1$, and the angle 1*i* on *i*1, which in the dodecahedron equals 120°, is in the zircon crystal equal to 123° 19′. In the figure here given the crystal has been drawn and the planes lettered with reference to the axes of the dodecahedron, and this must be borne in mind when comparing it with other figures of zircon. The most striking peculiarity of the crystals is the strong curvature of the terminal faces, which has been indicated in the figure, and which, as already intimated, renders accurate measurements impossible. Nevertheless, within the limits of necessary uncertainty the angles measured the same as those of zircon. The small planes not lettered on the crystal for want of space are *ii* and *i*3.

2.



The color both of the crystal and the powder is brownish-red,

and this color is not altered by ignition. Luster more or less adamantine on different specimens, evidently varying with the degree of alteration, and becoming more brilliant after ignition. Fracture after ignition conchoidal and very brilliant, but varying on the natural crystals, like the luster, with the degree of alteration. There is no distinct cleavage. Hardness before ignition from 5 to 5·5; after ignition from 7 to 7·5. Specific gravity before ignition from 3·985 to 4·040, the extreme limits observed; after ignition 4·095. Before the blowpipe the mineral is infusible. In a closed tube it gives off water, which has at first an alkaline reaction, but becomes acid when the mineral is heated more intensely. With bisulphate of potash gives slight reaction for fluorine. The powder dissolves with some difficulty in melted borax, giving only the reaction for iron. In phosphorus salt it dissolves only with great difficulty and incompletely, giving in the reducing flame, even when treated with tin on charcoal, a colorless glass. The mineral is partially decomposed by hydrochloric acid; more perfectly by strong sulphuric acid, and completely by fusion with carbonate of soda. An imperfect analysis gave the following results:

Silica, - - - - - - - -	27·90
Zirconia, - - - - - - - -	66·93
Sesquioxyd of iron with trace of manganese, -	2·57
Water, - - - - - - - -	2·19
	99·59

These numbers must give very nearly the composition of the material analyzed; but the composition must vary with the degree of alteration, and probably no two specimens would give precisely the same result. The material used was the best I could command, but not so good as might be desired, and I am happy to learn that a more trustworthy analysis will soon be published. On comparing these numbers with Scheerer's analyses of malacone, it appears that the amount of silica is somewhat greater in the original specimens, but the difference is evidently the result of further alteration. The zirconia was examined for other earths and metallic oxyds, but without positive results. No distinct indications of titanium could be obtained with the blowpipe, although it is possible that in the presence of so large an amount of zirconia a small amount might have escaped notice. The zirconia separated from the mineral was converted into chlorid, and the solution when evaporated crystallized to the last drop, forming a large mass of white silky needles. A solution of this chlorid, still acid to litmus paper, turned turmeric paper orange-yellow. In a solution of the same chlorid, oxalic acid produced a voluminous precipitate, which, when the solu-

tion was cold, readily dissolved in an excess of the reagent, and the more readily the larger the quantity of free hydrochloric acid present. If the solution was heated to boiling during the precipitation, the precipitate was not easily redissolved; but by digesting it for several hours with a very large excess of oxalic acid complete solution was finally effected. In a similar solution of the chlorid, a strong solution of sulphate of potash produced a precipitate, which in the presence of free hydrochloric acid readily dissolved in an excess of the reagent if the solution was kept cold. But if the solution was heated during the precipitation, the precipitate did not thus redissolve; but it immediately disappeared on adding a small amount of dilute sulphuric acid. From a solution of the chlorid of zirconium, ammonia throws down a gelatinous precipitate, but this precipitation was entirely prevented by the addition of tartaric acid. The hydrate thus obtained, when heated before the blowpipe, became intensely luminous and changed into a hard granular powder insoluble in all dilute acids. After digesting it, however, for several hours in strong sulphuric acid, it was converted into a sulphate, which dissolved completely on diluting the acid with water. These reactions appear to indicate that the zirconia was quite, if not entirely, free from an admixture of other earths, and the manner in which its reactions are modified by the temperature is the probable explanation of the confusion on the subject which is found in many text-books. The two modifications of zirconia, distinguished by Berzelius, seem to be repeated in many of its compounds, and malacone stands in the same relation to ordinary zircon that the soluble oxalate and sulphate do to the insoluble varieties. The malacone at Rockport is unquestionably in process of alteration, but whether the original mineral was the ordinary zircon or what we may call the normal malacone, I have not yet been able to determine.

(Nov., 1891, 20,000)

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